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(54) METHOD FOR DETERMINING THE AUTHENTICITY, THE VALUE AND THE DECAY LEVEL OF BANKNOTES, AND SORTING AND COUNTING DEVICE

(57) The present invention is used for sorting old or false banknotes, for determining their payment value as well as for searching and for detecting them through the production of full images of both sides of said banknotes. This invention can also be used for analysing the whole set of decay signs. The device for sorting and counting banknotes includes a control unit, a single-piece feeding unit whose supply speed is automatically adjusted according to the dimensions of the banknote, a transport system, a forwarding and counting unit, and a unit for separating the flow of banknotes and for directing them towards one of the storage baskets. The unit for determining the authenticity, the value and the decay level includes scanning devices used for producing a visible image and an infrared image, and also for producing a visible image and an induction-generated image.

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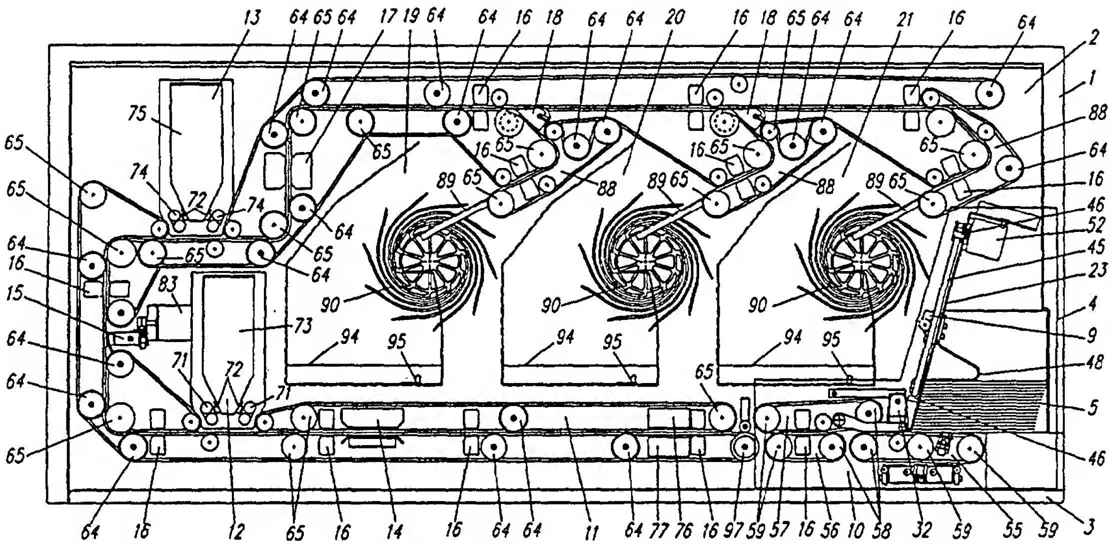

FIG.1

Description

PERTINENT ART

[0001] The invention is pertinent as to arts and devices for checking and determining authenticity, value and unfitness (decay) degree of banknotes, for their counting and sorting. It can be used in bank sorters to sort bills (bank notes), to determine their payability, to search for and to find unfit and counterfeit notes.

[0002] The note sorting and counting device is designed for automatic processing of notes of any issue, value and country. The process on which the operation of the device is based consists in determining authenticity, value and decay level of a note using full images - obtained with scanning devices - of both note sides in the visible spectral range, in the infrared spectral range and an induced image obtained under illumination in the ultraviolet spectral range; said images are transmitted to and processed in a computing unit where obtained images are compared to reference images with the help of preinstalled pattern recognition software.

[0003] The device automatically sorts "fit" notes (fit for further circulation) and "unfit" notes (subject to be destroyed because of poor physical condition) into separate pockets. The notes not matching a specified value or reference, having security feature faults, stuck together and unrecognizable notes are sorted into a separate pocket for further examination by an expert. The sort parameters (criteria) can be changed and corrected by the user according to his requirements through an interactive sort parameter regulation interface with the help of a display and a keyboard. The device keeps a log of its operation and therefore can fulfill registration and control functions.

PRIOR KNOWLEDGE

[0004] Known is the note sorting and counting device De La Rue 3700 of the firm De La Rue [1], that uses - for determination of note value and authenticity - a process based on the checking of availability of marks at certain points of notes with the help of infrared and ultraviolet detectors. To secure notes against counterfeits, pictures are printed on notes with so-called metameric inks; these pictures cannot be seen with a naked eye and only reveal themselves in the infrared spectrum. Knowing a concrete infrared image, it is possible to develop a detector that checks several certain points on the note surface for availability or absence of metameric ink. This detector is a pair: infrared source and photodetector that receives induced radiation from paper. If there is no metameric ink the photodetector is exposed to reflected light, if such ink is available the light stream at the photodetector decreases.

[0005] If a note is illuminated with ultraviolet radiation, induced visible radiation appears. Knowing a concrete ultraviolet image, it is possible to develop a detector that checks several certain points on the note surface for availability or absence of induced image. This detector is a pair: ultraviolet source and photodetector that receives induced radiation from paper. If there is induced image the photodetector is exposed to reflected light, if no such image is available the light stream at the photodetector decreases.

[0006] A shortcoming of this method is the checking of just several points on the surface of a note and not of the whole surface for availability or absence of image.

[0007] In the known method, decay level is checked with a microphone detector by the noise level of a note being crumpled; thus such substantial unfitness features as dirty spots and inscriptions can remain unnoticed.

[0008] In the known method, value of the note is checked with a special detector that represents an illuminator and a collection of light conductors gathering the reflected light at several note surface stripes, these light conductors are bundled together at the end and transmit the integral light intensity to the photodetector. When a note passes through under the detector, obtained at the photodetector are different integral light intensity curves depending on value. This method doesn't guarantee correct determination of note value.

[0009] The known machine has a single note feeding unit; a transportation system to advance notes to detectors of the passage control assembly and to count notes; an authenticity, value and unfitness determining assembly; available are a note stream splitting assembly for directing notes to one of the stacking units depending on a decision taken by the computing unit on the basis of data received from detectors; three stacking assemblies with vessels for stacking of the sorted and counted notes: one - for the fit ones, another - for the unfit ones, the third one - for the notes whose authenticity and value are doubtful. The shortcoming of the known machine is the necessity to readjust and replace the detector set before going over to another kind of notes, for instance, of another country. To redesign, manufacture and adjust another system of detectors to a new kind of notes is time-consuming, requires substantial resources and efforts as well as big financial expenditures.

INVENTION DISCLOSURE

[0010] The task of this invention is development of a method to determine banknote authenticity, value and decay level, said method being based on the scanning of the note with scanning devices allowing to obtain full images of

both note sides in the visible spectral range, in the infrared spectral range and an induced image (luminescent and/or fluorescent) appearing under illumination in the ultraviolet spectral range for high reliability with the subsequent image processing using a computing unit, and creation of a compact note sorting and counting device not requiring hardware changes when banknote is changed for another kind.

[0011] Essence of method is that the note is scanned with scanning devices what results in obtaining full images of both note sides in the visible spectral range, in the infrared spectral range and an induced image appearing under ultraviolet illumination. The images obtained are transferred to a computing unit in which they are compared to reference ones with the help of pattern recognition software and a decision is taken on authenticity, value and decay level of a note. The trainable pattern recognition software installed at the computing unit allows to recognize note images presented to it and to answer the question to which extent the entered image matches the reference one. The software can recognize complete matching of images, partial matching of images, complete mismatching of images, matching and mismatching of particular image fragments.

[0012] To determine value and decay level of a note, the software compares the obtained image in the visible spectral range with the reference one. If the images mismatch completely, the software decides that the note has a different value; if the images mismatch partially (spots, inscriptions, tears on the note, etc.) the software decides what is decay level of the note. To determine authenticity of a note, the software compares full infrared and induced image obtained under illumination in the ultraviolet spectral range with the reference image. If the images mismatch completely, it is decided that the authenticity of the note must be doubted. In case the images mismatch partially, the availability or absence of pictures is checked in special security zones on the note. If security zones mismatch it is decided that the authenticity of the note must be doubted.

[0013] The software allows to analyze a complex of note unfitness features: wear, spots, inscriptions, missing pieces at edges, folded and missing corners, holes, closed tears at edges.

[0014] The note image obtained in the visible spectral range, the note image obtained in the infrared spectral range, the induced image obtained under illumination in the ultraviolet spectral range are analyzed and decision rules on classification of notes into one of three classes (fit, unfit, suspect) are built on the basis of the threshold data determined by an expert.

The sequence of steps during note sorting is as follows:

[0015] Suppose a note image M x M pixels is received from the scanning device. Let us denote the set of image points by $\Omega = (0, M] \times (0, M] \in R^2$. In addition, each pixel (i,j) is juxtaposed a region:

$$\{(\xi,\eta) \in \Omega, \xi \in (j-1, j], \eta \in (i-1, i]\},$$

the point $(i,j) \in \Omega$ is the upper right comer of the pixel's region.

[0016] Suppose Ω_R is a set of image points belonging to a note being processed at the moment, Ω_D is a set of image points belonging to the reference note.

[0017] The main idea of note sorting consists in representation of the initial note image defined by the function $z = f(\xi,\eta)$ with the collection G_1, G_2 ,..., G_n of numeric characteristics, so that then a conclusion on belonging of the note to one of the below classes is made from the decision rule:

1. fit
2. unfit
3. suspect.

[0018] To define such numeric characteristics, let us split Ω_R into a set of ***R-blocks*** (recognition zones) $R_1, R_2, \ldots, R_n$, where $R_i \subseteq \Omega_R$, i=1, ...,n are quadratic (eventually overlapping) $B \times B$ pixel fragments of the image and $\bigcup_i R_i = \Omega_R$. Let us also consider a set of ***D-blocks*** (comparison zones at the reference note): where $D_1, D_2, \ldots, D_n$ are quadratic (eventually overlapping) $B \times B$ pixel fragments and $\bigcup_i D_i = \Omega_D$.

[0019] In real images there are almost always noises. Therefore let us consider note image $z = f(\xi,\eta)$ as realization of a stochastic process of two variables, i.e. as a stochastic field in which certain probability characteristics are inherent.

[0020] Let us begin the determining of statistical characteristics with calculation of initial and central moments. In probability theory, initial moments m_k of k-th order are calculated by the general formula

$$m_k = \sum_i x_i^k p_i ,$$

where x_i is some value of a discrete random parameter X, $p_i = P\{X = x_i\}$ is probability with which the random parameter X assumes value x_i.

[0021] Mathematical statistics operate on estimations of said moments. As applied to image analysis the formula takes on the form:

$$m_k = \frac{1}{B \times B} \sum_{i=1}^{B} \sum_{j=1}^{B} \left(f(\xi, \eta)\right)^k .$$

[0022] In probability theory, central moments u_k are defined with the expression:

$$u_k = \sum_i (x_i - m_1)^k P_i .$$

[0023] For practical usage of said formula it is necessary to estimate the average value m_1 in advance. Therefore let's use known formulas for counting initial moments over as central moments:

$$u_2 = m_2 - m_1^2$$

$$u_3 = m_3 - 3m_1 m_2 + 2m_1^2$$

$$u_4 = m_4 - 4m_1 m_3 + 6m_1^2 m_2 - 3m_1^4.$$

[0024] We shall also be interested in entropy and statistics related to central moments:

$$\sigma = \sqrt{u_2} \text{ - mean square deviation,}$$

$$g_1 = \frac{u_3}{\sigma^3} \text{ - asymmetry coefficient,}$$

$$g_2 = \frac{u_4}{\sigma^4} - 3 \text{ - coefficient of excess,}$$

$$I = -\sum_i p_i \log_2 p_i \text{ - entropy.}$$

[0025] Very important information for analysis of note unfitness features is information on spatial frequency defined as the speed of change in brightness of image elements divided by the distance at which this change happens. Information on spatial frequency allows us to use spatial filters for intensification or deletion of components with a certain frequency, for highlighting of some image features.

[0026] In general the spatial filtration process can be described in the following way:

Suppose

$$f(\xi,\eta)=\begin{vmatrix} a_{11} & a_{12} & \cdots & a_{1M} \\ a_{21} & a_{22} & \cdots & a_{2M} \\ \cdots & \cdots & \cdots & \cdots \\ a_{M1} & a_{M2} & \cdots & a_{MM} \end{vmatrix}$$

and

$$h(\xi,\eta)=\begin{vmatrix} b_{11} & b_{12} & \cdots & b_{1M} \\ b_{21} & b_{22} & \cdots & b_{2M} \\ \cdots & \cdots & \cdots & \cdots \\ b_{M1} & b_{M2} & \cdots & b_{MM} \end{vmatrix}$$

are initial image and weight function of the filter, respectively, whereas

$$F_f(u,v)=\frac{1}{M}\cdot\sum_{\xi=1}^{N}\sum_{\eta=1}^{N} f(\xi,\eta)\cdot\exp\left[-\frac{2\pi i}{M}(u\xi+v\eta)\right]$$

and

$$F_h(u,v)=\frac{1}{M}\cdot\sum_{\xi=1}^{N}\sum_{\eta=1}^{N} h(\xi,\eta)\cdot\exp\left[-\frac{2\pi i}{M}(u\xi+v\eta)\right]$$

are their Fourier transforms. Then $f' = f \otimes h = F^{-1}\,(F_f\,(u,v)\cdot F_h(u,\ v))$ is the filtration result of image f using the filter with the weight function h.

[0027] We have examined basic image analysis and processing methods applied in our banknote sorting software.

[0028] Note unfitness analysis occurs in several steps in blocks $R_i \subseteq \Omega_R$, i = 1, ...,n. For each block $R_i \subseteq \Omega_R$, i = 1,..., n some functional of the state of zone is calculated, said functional being determined at every step of work with regard to peculiarity of the feature being analyzed. The functional being calculated assumes the highest value at the reference zone and decreases at less similar zones. The obtained function value is compared to the threshold value determined as the maximum percentage deviation from value of the functional at the reference zone, and a decision is taken on the zone status for the given step.

[0029] Step 1. Determining value and decay level in the visible spectral range.

[0030] Unfitness is understood as a complex of note unfitness features: wear, spots, inscriptions, missing pieces at edges, folded and missing corners, holes, closed tears at edges.

[0031] Suppose $f(\xi,\eta)$ is image of a current note in the visible spectral range, $f^p(\xi,\eta)$ is image of the reference note in the visible spectral range. Initially, images of the reference note and a current note are split into **R** and **D** blocks described above. For every zone of the reference note and a note being analyzed, statistical characteristics $m_1,m_2,m_3,m_4,u_2,u_3,u_4,\sigma,g_1,g_2,I$ are calculated.

[0032] To determine note value, we perform filtration of the zone R_i, i 1,2,...,n with a filter whose frequency characteristic is $F_h(u,v) = F^*_{\overline{Di}}$, (1), where F_{D_i} is Fourier transform of the zone D_i, $*$ is an integral conjunction sign. Thus defined is the filter $F^*_{\overline{Di}}$, coordinated with the data pattern R_i to be recognized and its mutual correlation with a specified image is performed. If the image contains an interesting pattern, then in the origin of coordinates of the system's output plane $f'(\xi,\eta)$: $(\xi,\eta) \in R_i$, as a result of correlation, a bright light spot is formed that points to availability of the pattern being recognized and position within the desired image.

[0033] Let us assume that the zone state function equals to $G_i = \rho\sum_j(w_j * \alpha_{ij})$, where α_i=$[m_1,m_2,m_3,m_4,u_2,u_3,u_4,\sigma,g_1,g_2,I,m'_{\overline{1}},m'_{\overline{2}},m'_{\overline{3}},m'_{\overline{4}},u'_{\overline{2}},u'_{\overline{3}},u'_{\overline{4}},\sigma',g'_{\overline{1}},g'_{\overline{2}},I']$ is an initial vector of the zone features, components $m'_{\overline{1}},m'_{\overline{2}}$,... are statistical characteristics of the zone after filtration, w_j are empirically obtained weights of initial features.

[0034] When determining value of a note we shall take into account that pattern correspondence depends on both

general (integral) similarity of the whole note and availability/absence of picture in control zones.

[0035] To estimate the general correspondence, let us assume that the note state function is equal to

$$\Phi = \sum_{i=1}^{n} \varphi_i ,$$

where

$$\varphi_i = \begin{cases} 1, if\ G_i \geq G_i^{\max} \\ 0, if\ G_i < G_i^{\max} \end{cases} .$$

[0036] If for the specified threshold Φ^{max}, $\Phi \geq \Phi^{max}$ then the control zones are checked for correspondence, otherwise the note value doesn't match the specified one, the note assumes the property "suspect".

[0037] To estimate correspondence in control zones, let us introduce an additional binary vector l_i (0,1), i = 1, ..., n, where l_i = 1 for control zones, l_i = 0 for other zones. If $\Phi = \prod_{i=1}^{n} (l_i \cdot \varphi_i) = \sum_{i=1}^{n} l_i$ - value doesn't match the specified one, let us go over to the analysis of note unfitness features. Otherwise the note is considered to be suspect.

[0038] To estimate the wear degree, let us assume that the note state function is equal to

$$\Phi = \sum_{i=1}^{n} G_i .$$

[0039] If for the specified threshold Φ^{max}, $\Phi < \Phi^{max}$, then the note is considered to be worn.

[0040] To reveal spots, let us change (1) as follows:

$F_h(u,v) = A(u,v) \cdot F^{*}_{\overline{Di}}$,

where $A(u,v)$ is frequency response of the low frequency filter. Let us use the same state function as for determination of integral correspondence of values.

$$\Phi = \sum_{i=1}^{n} \varphi_i ,$$

where

$$\varphi_i = \begin{cases} 1, if\ G_i \geq G_i^{\max} \\ 0, if\ G_i < G_i^{\max} \end{cases} .$$

[0041] If for the specified threshold Φ^{max}, $\Phi < \Phi^{max}$, then the acceptable area of spots exceeds the threshold.

[0042] To reveal inscriptions, let us change (1) as follows:

$$F_h(u,v) = A(u,v) \cdot F^{*}_{D_i},$$

where $A(u,v)$ - is frequency response of the high frequency filter. Let us use the same state function as for determination of integral correspondence of values.

$$\Phi = \sum_{i=1}^{n} \varphi_i ,$$

where

$$\varphi_i = \begin{cases} 1, if\ G_i \geq G_i^{\max} \\ 0, if\ G_i < G_i^{\max} \end{cases}.$$

[0043] If for the specified threshold Φ^{max}, $\Phi < \Phi^{max}$ then the acceptable area of spots exceeds the threshold.

[0044] To analyze missing pieces along the edges, let us make advantage of the fact that brightness of the background is substantially different compared to the brightness of note edges. Let us separate the edges and determine a tolerance in pixels to define distance from a border point to the nearest side of the rectangle placed around the note. If at a certain point the maximum tolerance condition is violated and the point does not belong to the note corner neighborhood specified by the expert, then there are missing pieces along the edges of the note.

[0045] To determine folded corners, let us plot a regression curve $y = ax + b$ by edge points situated in note corner neighborhood. If for at least one point the distance to the straight line is bigger than the specified one, then the corner is considered to be torn off (missing), otherwise it is considered folded.

[0046] A hole is a note image section whose intensity is close to the dynamic range of background brightness. Let us go through all image pixels of the note being processed and separate coherent regions whose intensity is close to the one of the background. If the area of at least one region exceeds the tolerable one, then there are holes in the note.

[0047] Unlike a missing piece, a tear doesn't cause geometrical distortion therefore it does not necessarily appear in note images. Tear recognition is a search for lines beginning from note edge in the infrared spectrum. To search for them, let us change (1) in the following way:

$F_h(u,v) = A(u,v)$, where $A(u,v)$ is frequency characteristic of the high frequency filter, for instance, Laplacian

$$F^{-1}(A(u,v)) = \begin{Vmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{Vmatrix}$$

and we filter only the current image regions adjacent to note edges. Upon clustering and calculation of the area of lines beginning from note edge, it is decided that there are closed tears in the note, under condition that the total area of tears exceeds the threshold area.

[0048] Step 2. Ultraviolet security check is similar to value determination, but for this procedure we use an induced image obtained after illumination of the note in the ultraviolet spectrum.

[0049] Step 3. Infrared security check is similar to value determination, only in the infrared spectrum.

[0050] It is necessary to note that thresholds $\Phi^{max}, G\frac{max}{i}$, $i = 1, 2, ..., n$ are selected at every step of software operation separately and are adjustable parameters directly influencing the note sorting level. A note is considered unfit, if it has at least one unfitness feature.

[0051] The proposed method of determining authenticity, value and decay level of banknotes is realized in a banknote sorting and counting device comprising a case in which a control unit with an interactive interface designed for adjusting of sort parameters by means of monitor and keyboard, a single note off pile feeding unit, a transport system for feeding notes to detectors of the unit for note counting and note passing control, a banknote authenticity, a value and decay level determining unit, a banknote stream splitting unit for directing the notes into one of the stacking units with vessel depending on a decision taken by the computing unit on the basis of data retrieved from detectors, stacking units with vessels for stacking counted and sorted banknotes, wherein positioning parameters of both magnetic mark detector and aligning plates of the single note feeding unit, rotation speed of the stacker wheel and adjustment of the clearance between surface of rings of separating unit and surface of belts of the feeding conveyor are controlled automatically with the control unit, depending on the size of banknotes loaded into the device. The feeding transportation assembly of the unit feeding notes one by one off the pile has its separate drive with automatic adjustment of the feeding speed depending on the size of the banknote to be loaded into the device. A banknote pile pressing assembly is introduced to ensure a stable contact between the lowest banknote in the pile and the transportation belts of the feeding assembly equipped with a detector checking presence of banknotes in the pile holder and connected to the press assembly drive control. The single banknote feeding unit is equipped with moving guides with a drive for strictly symmetrical positioning of the banknote pile in relation to longitudinal axis of the transportation mechanism regardless of the banknote size. The banknote authenticity, value and decay level determination assembly comprises scanning devices allowing to

obtain full image of both sides of the banknote in the visible spectrum range, in the infrared spectrum range and induced image obtained during illumination in the ultraviolet spectrum range, connected to the computing unit arranged in the control unit that processes data retrieved from scanning devices with the help of pattern recognition software that is preinstalled and transfers the decision on authenticity, value and decay level of the banknote to the banknote stream splitting assembly in order to direct counted and sorted banknotes to one of the stacking assemblies with vessels. A scanning device for retrieval of banknote images form one split light stream in the visible and infrared spectrum ranges comprises illuminators for visible and infrared light, a lens, a semitransparent mirror, light filters for separation of the visible spectrum range and the infrared spectrum range, an image reading device. A scanning device for retrieval of banknote images from one split light stream in the infrared spectrum range and induced image obtained during illumination in the ultraviolet spectrum range comprises ultraviolet illuminators and infrared illuminators, a semitransparent mirror, an optical band light filter passing through the visible spectrum range and a light filter for separation of the infrared spectrum range, an image reading device.

[0052] The banknote authenticity, value and decay level determining unit comprises a scanning device for obtaining images in the visible and the infrared spectra, a scanning device for obtaining image in the infrared spectrum range and induced image during illumination with ultraviolet light, both being connected to the computing unit that processes data retrieved from the scanning devices with the help of preinstalled pattern recognition software and outputs a decision on the state the banknote is in. Quantity-produced scanning devices (scanners) designed to obtain images of paper documents and enter these images into a computing unit do not allow to obtain a paper document image in two spectrum ranges (for instance, visible and infrared) simultaneously what makes them unsuitable for determining authenticity of banknotes. They comprise an illuminator, a lens, a CCD array, an electronic device for reading image from the CCD array and transferring it to the computing unit. A paper document is illuminated and with the help of a lens its image is focussed on the CCD array, where it is converted to electronic form with electronic device for reading image from the CCD array and in this electronic form it is transferred to computing unit.

[0053] We use a scanning device for obtaining banknote images in the visible and infrared spectrum ranges from one split light stream, as represented in Fig. 9.

[0054] Said technical result is reached by mounting - after lens 104 - a semitransparent mirror 105 thanks to which a banknote image is transferred to two CCD arrays 108 arranged on one optical axis. Moreover, before one CCD array we mount a light filter for separating the visible spectrum range 106 and before the other one - a light filter for separating the infrared spectrum range 107. Additionally to the illuminator in the visible spectrum range 71, an infrared illuminator 72 is mounted on the scanning device.

[0055] As is known, in authentic banknotes the infrared image differs substantially from the visible one. By viewing these zones on the display, operator has opportunity to determine authenticity of the note. If pattern recognition software is installed on the computing unit, authenticity of the banknote is determined automatically.

[0056] The scanning device for obtaining note images in the visible and the infrared spectra works in the following way.

[0057] Light stream is focussed with the lens 104, then split with the semitransparent mirror 105 in two streams and transferred to the CCD arrays 108. Light filters 106 and 107 mounted before each CCD array create a visible image at one CCD array and an infrared image at the other one. Electronic device 109 reads images from the CCD arrays and transfers them to the computing unit.

[0058] Applied in the suggested machine is also a scanning device for obtaining both a note image in the infrared spectrum and an induced image created under illumination in the ultraviolet spectrum from one split light stream. This device is shown in Fig. 10.

[0059] Said technical result is reached by mounting - after lens - a semitransparent mirror 105 thanks to which a banknote image is transferred to two CCD arrays 108. Moreover, we mount a light filter for separating the infrared spectrum range 107 before one CCD array and an optical band filter passing through the visible spectrum range 110 before the other one. Instead of a usual illuminator, ultraviolet illuminator 74 and additionally infrared illuminator 72 are mounted on the scanning device.

[0060] When a note is scanned, two images are taken: infrared one and an induced image created under illumination in the ultraviolet spectrum. As is known, in authentic banknotes the infrared image and the induced image created under illumination in the ultraviolet spectrum differ substantially from the visible one. By viewing these zones on the display, operator has opportunity to determine authenticity of the note. If pattern recognition software is installed on the computing unit, authenticity of the banknote can be determined automatically.

Short description of Figures

[0061] Fig.1. Drawing of the device;

[0062] Fig.2 Diagram of the device drive;

[0063] Fig.3 Moving guides of the pile holder of the single note feeding unit;

[0064] Fig.4 Carriage drive of the press unit of the single note feeding unit;

[0065] Fig.5 Separating assembly of the single note feeding unit;
[0066] Fig.6 Drive of the magnetic mark detector;
[0067] Fig.7 Drive of the banknote stream splitting unit;
[0068] Fig.8 Drive of the stacker of the note stacking assembly;
[0069] Fig.9 Diagram of the scanning device for obtaining banknote images in the visible and infrared spectra;
[0070] Fig.10 Diagram of the scanning device for obtaining banknote images in the ultraviolet and infrared spectra;
[0071] Fig. 1 Diagram of the laser detector of double notes;
[0072] Fig. 12 Block diagram of action sequence for determination of value and. unfitness of banknotes;
[0073] Fig.13 Block diagram of action sequence for determination of authenticity of banknotes;
[0074] Fig.14 Block diagram of the control unit of the device for sorting and counting notes.

Industrial Embodiment of Invention

[0075] Banknote sorting and counting device "BARS" (see Fig. 1,2) comprises the following main assemblies: case 1 with mounting plate 2 and ground plate 3 designed for placing the device on a desk, control unit 22, unit 4 for feeding single notes off pile 5 comprising pile holder equipped with moving guides 6 and 7 for strictly symmetrical positioning of banknote pile in relation to longitudinal axis of transportation mechanism of the device, separating assembly 8 with drive of clearance adjusting device, banknote pile pressing assembly 9 with drive of lift mechanism, feeding assembly 10 with drive, banknote transportation systems 11 with stabilized drive, banknote authenticity, value and decay level determination assembly comprising scanning device 12 for obtaining images in the visible and the infrared spectrum range, scanning device 13 for obtaining images in the infrared spectrum range and secondary emission images obtained during illumination in the ultraviolet spectrum range, ultraviolet detector 14; magnetic mark detector 15, banknote passage control and counting unit 16; double note detector 17; banknote stream splitting assemblies 18; stacking assembly for fit notes 19; stacking assembly for unfit notes 20; stacking assembly for notes whose authenticity and value is doubtful 21.
[0076] Pile holder of the single note feeding unit with positioning guides of banknote pile in relation to longitudinal axis of transportation mechanism with drive (see Fig. 1, 3, 4) comprises limiting plate 23 designed to support front part of banknote pile, with a slot in the middle for shifting of press device, front guide 6 and rear guide 7 representing smooth polished plates. Each guide is attached to a carriage 24 that can move along two cylindrical legs, the front one along long legs 25, the rear one along short legs 26, attached in parallel on mounting plate. Carriages are mechanically connected to timing belt 27 arranged between them. One end of belt is passed over a smooth pulley 28 and the other end is engaged with cog-pulley 29 fastened on shaft 30 of electrical motor. When the shaft of electrical motor rotates anti-clockwise, the guides converge simultaneously at the center, and when the shaft of electrical motor rotates clockwise, the guides diverge. The rear guide has support pulley 31. The separating assembly 8 with drive of clearance adjusting device (see. Fig. 1, 2, 5) comprises case 32 on which there are two axles 33 with non-drive rollers 34 and drive shaft 35 attached to which are pulleys 36 with grooves for rings and drive cog-pulley 37. Over frame 38, case is fixed on axle 39 fastened rigidly to mounting plate. Clearance is regulated thanks to tilting of case and frame, in relation to axis. Claw 40 attached to case and transferring movement to it is pressed to nut 42 with spring 41 so that when screw 43-attached coaxially to shaft of electrical motor 44 - rotates in one or the other direction, mechanism of separating assembly is lifted or lowered. Two auxiliary spring-loaded pressure rollers are arranged on two sides of separating assembly. These rollers consist of pulley 99, lever 100, axis 101 rigidly fastened to mounting plate and spring 102 each. Thanks to the spring the rollers are constantly pressed to surface of transport belts and increase the contact between notes and transport belts in the area of separating assembly.
[0077] Banknote pile press assembly 9 with drive of lift mechanism (see Fig. 1, 4) consists of two cylindrical guides 45 which are attached with holders 46 to limiting plate 23 designed to support the front part of the banknote pile and along which carriage 47 moves on which press 48 - made of bent polished sheet - is fastened, the press having a straight section parallel to the upper part of the banknote pile. Press and carriage move down along the guides under their own weight. Prior to loading of a banknote pile, press is lifted with lifting mechanism comprising timing belt 49 whose one end is passed over smooth pulley 50 and whose other end is engaged with cog-pulley 51 fastened on shaft 52 of electrical motor. Fastened between cog-pulley and smooth pulley is tie 53 whose size exceeds that of slot of hook 54 fastened on carriage of press over which a belt is passed. During lifting, the tie rests on the hook and lifts the press. In working position, when notes are being sorted, the tie is in the lowest position at the smooth pulley.
[0078] The feeding transportation assembly 10 (see Fig. 1, 2) comprises three unconnected to each other sections: two lower transporter sections 55, 56 and one upper transporter section 57. Carriers of transporters are round endless belts made of friction material and stretched on drive drums with grooves 58 fastened on shafts and driven drums 59 mounted on axles. The feeding transport assembly is driven with two-sided timing belt 60 engaged with cog-pulleys 61 fastened on shafts of drive drums and with cog-pulley 62 fastened on the shaft of drive electric motor 63.
[0079] Banknote transportation system 11 (see Fig. 1, 2) comprises a number of sections of upper and lower trans-

porters whose carriers are round endless belts made of friction material and stretched on drive drums with grooves 64 fastened on shafts and driven drums 65 mounted on axles and is designed for passing banknotes sequentially through scanning devices, detectors and passage control and counting assemblies. For continuity in the transport system in the gaps between scanning devices 12, 13 and magnetic mark detector 15 the passage from one section to another is done on a drum thanks to symmetrical shift in position of a pair of drawing round belts of the next section to neighboring grooves. For synchronicity in operation of different transport system parts, the driving is done with one double-sided timing belt 66 engaged with cog-pulleys 67 fastened to shafts of section drive drums and with cog-pulley 68 of drive electrical motor 69 featuring a rotation speed stabilization system. Smooth pulleys 70 fastened to axles are designed to give belts a specified direction.

[0080] Scanning device for obtaining banknote images from one split light stream in the visible and the infrared spectra 12 consists of two visible spectrum illuminators 71, infrared spectrum illuminators 72 and case 73 inside which the following parts are arranged (see Fig. 9): lens 104, semitransparent mirror 105, light filter for separation of the infrared spectrum range 107, light filter for separation of the visible spectrum range 106, CCD array 108, electronic devices 109 for reading images from CCD arrays. Data obtained from scanning device are processed with computing assembly arranged in control unit 22 of sorting device.

[0081] Scanning device for obtaining banknote images from one split light stream in the infrared spectrum and secondary emission image created under illumination in the ultraviolet spectrum 13 (see Fig. 1) consists of two ultraviolet spectrum illuminators 74, infrared spectrum illuminator 72 and case 75 inside which (see Fig.10) the following parts are arranged: lens 104, semitransparent mirror 105, light filter for separation of the infrared spectrum range 107, optical band light filter passing the visible spectrum range 110, CCD array 108, electronic devices 109 for reading images from CCD arrays. Data obtained from scanning device are processed with computing assembly arranged in control unit 22 of sorting device.

[0082] Ultraviolet detector 14 designed to produce electronic signals for control unit of sorting device and showing luminance level of note in the ultraviolet spectrum is notorious and comprises case, ultraviolet illuminator, reflected light stream detectors with electronic signal producing assembly.

[0083] Magnetic mark detector 15 (see Fig. 1, 6) is designed to produce electronic signals on passing by magnetic marks for control unit of sorting device and consists of upper 76 and lower 77 magnetizing devices, magnetic sonde 78 mounted in guide 79 that - together with carriage 80 - moves along two parallel cylindrical legs 81 attached to mounting plate. Mechanism is driven by electrical motor 82 with drum 83 that is fastened to the shaft and over whose outer surface a string 84 (one turn) is passed that is fixed at two ends of carriage 80. When shaft of electrical motor rotates, the string shifts the carriage with magnetic sonde along legs (laterally to note movement direction).

[0084] Banknote passage control and counting assembly 16 (see Fig. 1) is designed to produce signals for control unit of sorting device, said signals indicating position of concrete banknotes in transportation mechanism's conveyor and in conveyor of feeding transporters of stacking assemblies (they are notorious and consist of light stream source, photodetector and assembly producing electronic signals).

[0085] Double banknote detector 17 (see Fig. 1) is designed to produce electronic signals for control unit of sorting device, said signals indicating detection of double banknotes in the conveyor of movement mechanism for their exclusion and sending to stacking assembly for suspect banknotes, said detector comprising light stream sources, photodetectors and assembly producing electronic signals. Laser double note detector also used by us (see Fig.11) comprises laser sensor and computing unit 116. Laser sensor comprises emitter in the form of laser diode 111, collimator lens 112, slit diaphragm 113, lens 114, photodetector array in the form of CCD array 115. Note thickness is measured in the following way. Laser beam creates a thin light line on pulley, on one or two notes in points A1, B1, C1 (see Fig. 11). They correspond to line image points on CCD array A2, B2, C2. Distance between basic position point of light line image A2, and points B2, or C2 is in proportion to thickness being measured. Signals from CCD - array come to computing assembly in which:

- coordinates of line image points on pulley and during passage of note are stored;
- specified thickness value of note is stored;
- "mean" thickness value of one or more notes is calculated and compared to the specified value.

[0086] Note stream splitting assembly 18 (see Fig. 1, 7) is designed to divert notes from basic direction along conveyor of movement mechanism to a stacking assembly and consists of two diverting elements (arrows) 85 fastened to axle 86 coaxially connected through clutch 103 to electrical turning device 87 that - upon being turned on - moves the diverting elements from initial lower position to an upper one by a certain angle.

[0087] Note stacking assemblies 19, 20, 21 (see Fig. 1, 8) have identical design and consist of conveyors 88, guide 89, stacker 90 (that is a disk with multi-entrance spiral-looking notches that is fastened in cantilever on axle 91 connected through clutch 92 to electrical motor 93) and stack vessel 94 in which banknote availability control device 95 is installed.

[0088] Control unit (see Fig.14) comprises:

- controller designed to produce electronic signals from magnetic mark detector, ultraviolet detector, banknote passage control and counting assembly, double banknote detector, control assembly for physical condition of banknotes, banknote availability control device for stacking assemblies;
- device that produces electronic signal of scanning device for obtaining images in the visible and the infrared spectra and of scanning device for obtaining images in the ultraviolet and the infrared spectra;
- movement system control assembly designed to receive data from electronic signal producing means and to give commands to mechanism control means;
- control device for mechanisms designed to drive note transportation system, feeding transport assembly, positioning guides, note pile press, separating assembly adjustment motor, note stream splitters, stackers, sonde of magnetic mark detector;
- devices that are designed to specify operation modes and visualize sorting and counting results and comprise monitor, keyboard and mouse.

[0089] Note sorting device operates in the following way.

[0090] Note pile 5 is placed in pile holder of single note feeding unit, with front part of pile resting on limiting plate 23, and base of pile lying on round belts of transporter 55 that are supported with non-driving drums of feeding assembly. With a little time delay, if there is a note pile in pile holder, drive of press assembly 9 begins to operate by lowering press 48 onto the upper part of note pile 5. Simultaneously begins acceleration of electrical motor 69 that sets main conveyor of note transportation mechanism 11 in motion. Electrical motor 63 of feeding transportation assembly 10 - by means of cog-pulley 62 fastened on shaft, double-sided timing belt engaged with cog-pulleys 61 fastened on shafts of driving drums of three sections and drive shaft of separating assembly - sets the round transportation belts and the friction rings of separating assembly in motion, with movement direction of friction rings being opposite to movement direction of transportation belts. Since friction force between the lowest note in a pile and transportation belts is higher than friction force between the notes within a pile, the lowest note is taken out of the pile with transportation belts, with other notes being oriented by profile of limiting plate 23. The lowest note of the pile is carried by transportation belts and fed through gap between outer surface of transportation belts and outer surface of friction rings of separating assembly 8. Since traction of transportation belts is higher than traction of friction rings of separating assembly, transportation belts effect upon a note being fed more than friction rings of separating assembly, and so the lowest note is carried further through single note feeding unit to acceleration conveyor. Interaction force between rings of separating assembly and the next notes substantially exceeds traction between neighboring notes, as a result of what all the next notes are returned by rings of separating unit back to pile 5. The same happens when feeding bound together, double, triple etc notes. Then a note passes through acceleration transportation conveyor consisting of upper 57 and lower 56 sections. Drive drums of these sections are connected to power shafts through free-wheel clutches 96. When a note is picked by take-up pulley 97 of transportation system's main conveyor, the note's movement speed increases because of difference in speeds of transportation mechanism's main conveyor and single note feed conveyor, so that thanks to free-wheel clutches 96 acceleration transportation conveyor reaches a higher speed than main speed of transportation belts of single note feed assembly, in which the notes are spatially separated at a section of acceleration transportation conveyor. Transporter belts carry the note consecutively through magnetizing device of magnetic mark detector, note passage and counting control units, ultraviolet detector, magnetic mark detector, scanning devices, double note detector and depending on physical condition the fit note stacking assembly or the unfit note stacking assembly is chosen and, correspondingly, that stream splitting assembly gets turned on that matches the given stacking unit, and if it is a suspect note, it goes straight down the main conveyor to the suspect note stacking assembly. When notes pass control assemblies, their parameters are checked, for instance, images in the visible spectrum, and, from combined data related to the given note and obtained from electronic signal producing assemblies, control unit decides into which category the given note is to be classified, for instance, it is considered fit. Control unit 22 determines the time it will take the note to approach diverting element 18 of stream splitting assembly before fit note stacking assembly 19 for its activation. When diverting element is turned on, the fit note is carried by feeding transporter of fit note stacking unit through passage and counting control assembly 16 to stacker 90 representing a disk with multi-entrance spiral-looking notches. Upon exiting the feeding transporter, the note moves along guide 89 and enters spiral-looking notch of stacker 90 where it slides to the end thanks to gathered momentum and stops. The stacker keeps on rotating and when the front end of the note reaches flat wall, the note is taken off the spiral and placed on the bottom of stacking vessel 94. As soon as a specified number of notes is reached in one of stacking units - fit or unfit, conveyor of feeding transportation assembly 10 is turned off, and conveyor of transportation system 11 stops when all notes remaining on conveyor are sent to suspect note stacking assembly 21. As soon as a batch of notes is taken out of a stacking assembly (19 or 20), the sorting and counting process resumes automatically.

[0091] Thus the invention being advanced allows to:

- increase reliability of authenticity, value and decay level determination, since not just separate points, but full image of both note sides in three spectra is analyzed.
- avoid necessity to make over the system of detectors when going over to a new kind of banknotes, said makeover requiring time and money, since the process applied for allows the user to adapt the sorting device to banknotes of another country by simply training the pattern recognition software installed on the computing unit for new note images.

References

[0092]

1.De La Rue Systems. Promotional material.

2.Certificate of Official registration of computer program "Universal pattern recognition system STARC" (No. 960128 of 18.04.96), possessor of right OOO "Firma Data-Center".

3.ProfScan 5000 Promotional material.

4.PARAGON 800 SP Promotional material.

5.ScanJet 5p Promotional material.

6.FILEMASTER Promotional material.

Claims

1. Method for determining the authenticity, the value and the decay level of banknotes, consisting in illumination of a banknote with visible, infrared and ultra-violet light, wherein a banknote is scanned with scanning devices, what results in obtaining full images of both note sides in the visible spectrum range, in the infrared spectrum range and an induced image (luminescent and/or fluorescent) as a result of illumination in the ultra-violet spectrum range; the images obtained are transferred to a computing unit at which pattern recognition software is installed in advance; with this the software images of the banknote to be analyzed are compared to reference images and, on the ground of developed decision rules, the note is classified into one of the three classes - fit, unfit or suspect: the value and the decay level are determined as follows: suppose $f(\xi,\eta)$ is an image of the current banknote in the visible spectrum range, $f^{p}(\xi,\eta)$ is an image of the reference banknote in the visible spectrum range, images of the reference and the current notes are split into ***R*** (recognition areas) and ***D*** (areas for comparison to reference notes) units, some statistical characteristics are calculated for every area of the reference note and the note to be analyzed, the value of a banknote is determined by filtering the area $R_i, i=1,2,...n$ with a filter having frequency response $F_h(u,v) = F^{*}_{\overline{Di}}$ (1), coordinated with data pattern D_i, subject to recognition, function of area state is considered to be equal to $G_i = \rho\sum_j(w_j * \alpha_{ij})$, where

α_i - area features' initial vector whose components are statistical characteristics of area before and after filtration,
w_j - empirically obtained weights of initial features, while determining a banknote value the integral correspondence function of state is considered to be equal to $\Phi = \sum_{i=1}^{n}\varphi_i$, where

$$\varphi_i = \begin{cases} 1, if \;\; G_i \geq G_i^{\max} \\ 0, if \;\; G_i < G_i^{\max} \end{cases}$$

If for the specified threshold $\Phi^{\max}$, $\Phi \geq \Phi^{\max}$,- then correspondence is checked in control areas, otherwise the value doesn't correspond to the specified one, and it is concluded that the note is suspect, for estimation of correspondence in control areas an additional binary vector $I_i(0,1), i=1,...,n$, is introduced, where $I_i = 1$ - for control areas, $I_i = 0$ - for other areas, if $\Phi = \prod_{i=1}^{n}(I_i \cdot \varphi_i) = \sum_{i=1}^{n} I_i$, - the value doesn't correspond to the specified one, analysis of note deterioration features begins, in other cases the note is considered to be suspect, for determination of the decay level the function of note state is considered to be equal to $\Phi = \sum_{i=1}^{n} G_i$, if for the specified feature $\Phi_{\max,}$, $\Phi < \Phi^{\max}$, the note is considered unfit, to reveal spots (1) is changed in the following way: $F_h(u,v) = A(u,v) \cdot F^{*}_{\overline{Di}}$, where $A(u,v)$ -

frequency response of low frequency filter, function of state is defined as for determination of integral correspondence of values $\Phi=\sum_{i=1}^{n}\varphi_i$,, where

$$\varphi_i = \begin{cases} 1, if \;\; G_i \geq G_i^{\max} \\ 0, if \;\; G_i < G_i^{\max} \end{cases}$$

If for the specified threshold Φ^{max},$\Phi < \Phi^{max}$,, it is concluded that the acceptable area of spots exceeds the threshold, to reveal (1) is changed in the following way:

$F_h(u,v) = A(u,v)\cdot F^*_{\overline{DI}}$, where $A(u,v)$) - frequency response of high frequency filter, function of state is defined as for determination of integral correspondence of values,

$$\Phi = \sum_{i=1}^{n} \varphi_i \;,$$

where

$$\varphi_i = \begin{cases} 1, if \;\; G_i \geq G_i^{\max} \\ 0, if \;\; G_i < G_i^{\max} \end{cases}$$

If for the specified threshold Φ^{max}, $\Phi<\Phi^{max}$, the acceptable area of inscriptions exceeds the threshold; for analysis of missing pieces along edges, the edges are found and a tolerance in pixels is defined, if the tolerance limit condition is not met for some point and the point doesn't belong to a note corner neighborhood defined by an expert, it is concluded that pieces of the note along its edges are missing; to determine folded comers a regression line $y=ax+b$ is plotted by edge points lying in a note comer neighborhood, if at least for one point the distance to the straight line exceeds the specified one, the corner is considered missing, otherwise - folded; for recognition of holes all image pixels of the current note are checked and coherent zones with intensity close to intensity of background are found, and if area of at least one zone exceeds the tolerable one it is concluded that there is a hole in the note; or recognition of closed tears along the edges (1) is changed as follows:

$F_h(u,v) = A(u,v)$), where $A(u,v)$ - frequency response of the high frequency filter, and only the zones neighboring the note edge are filtered in infrared light, the lines beginning from note edges are clustered and their areas are calculated, if the total area of tears exceeds the threshold, closed tears along edges are considered to be present; ultraviolet security is checked as in the case of the value determining, but on an induced image obtained upon illuminating the note in the ultraviolet spectral range;

infrared security (step 3) is checked as in the case of the value determining, but in the infrared spectral range, thresholds Φ_{max},, $G^{max}{}_i$,i=1,2....,n are selected for every step separately. A note is considered unfit, if it has at least one unfitness feature specified by the operator.

2. Banknote sorting and counting device comprising a case in which a control unit with an interactive interface designed for adjusting of sort parameters by means of monitor and keyboard, single note off pile feeding unit are arranged, a transport system for note feeding to detectors of the unit for note counting and note passing control, a banknote authenticity, the value and unfitness degree determining unit, a banknote stream splitting unit for directing the notes into one of the stacking units with vessel depending on a decision taken by the computing unit on the basis of data retrieved from detectors, stacking units with vessels for stacking counted and sorted banknotes, wherein positioning parameters of both magnetic mark detector (15) and aligning plates (6, 7) of the single note feeding unit (4), stacker wheel (90) rotation speed and adjustment of the clearance between surface of rings (36) of separating unit (8) and surface of belts of the feeding conveyor are controlled automatically with the control unit (22) depending on the size of banknotes loaded into the device, the feeding transportation assembly (10) of the unit (4) feeding notes one by one off the pile (5) has its separate drive with automatic adjustment of the feeding speed depending on the size of the banknote to be loaded into the device, a banknote pile pressing assembly (9) is introduced to ensure a stable contact between the lowest banknote in the pile and the transportation belts of the feeding assembly (10) equipped with a detector checking presence of banknotes in the pile holder and con-

nected to the press assembly drive control, the single banknote feeding unit (4) is equipped with moving guides (6, 7) with a drive for strictly symmetrical positioning of the banknote pile in relation to longitudinal axis of the transportation mechanism regardless of the banknote size, the banknote authenticity, the value and unfitness degree determination assembly comprises scanning devices (12, 13) allowing to obtain full image of both sides of the banknote in the visible spectrum range, in the infrared spectrum range and induced image obtained during illumination in the ultraviolet spectrum range, connected to the computing unit arranged in the control unit (22) that processes data retrieved from scanning devices (12, 13) with the help of pattern recognition software that is installed on it in advance and transfers the decision on authenticity, the value and unfitness degree of the banknote to the banknote stream splitting assembly (18) in order to direct counted and sorted banknotes to one of the stacking assemblies (19, 20, 21) with vessels (94), a scanning device for retrieval of banknote images from one split light stream in the visible and infrared spectrum ranges (12) comprising illuminators for visible (71) and infrared (72) light, a lens (104), a semitransparent mirror (105), light filters for selection of the visible spectrum range (106) and the infrared spectrum range, an image reading device (109); a scanning device for retrieval of banknote images from one split light stream in the infrared spectrum range and induced image obtained during illumination in the ultraviolet spectrum range (13) comprising ultraviolet illuminators (74) and infrared illuminators (72), a semitransparent mirror (105), an optical band light filter passing the visible spectrum range (110) and a light filter for selection of the infrared 25 spectrum range (107), an image reading device (109).

3. Device as claimed in claim 2, wherein the banknote press assembly (9) with the lift mechanism drive (Fig. 1,4) comprises two cylindrical guides (45) that are fastened with holders (46) to a limiting plate (23) designed to support the front part of the banknote pile and moves along which a carriage (47) on which a press (48) made of bent polished sheet is fastened, the press having a straight section parallel to the upper part of the banknote pile, the lifting of the press prior to loading a banknote pile being executed with the lifting mechanism comprising a timing belt (49) whose one end is passed over a smooth pulley (50) and whose other end is engaged with a cog-pulley (51) fastened on the shaft (52) of electrical motor, between the cog-pulley and the smooth pulley a tie (53) is fastened, its size exceeding the slot of the hook (54) fastened on the carriage of the press over which a belt is passed.

4. Device as claimed in claim 2, wherein the separating assembly (8) of the single note feeding unit is equipped with three rings made of friction material each of which is stretched on a roller, the three rollers shaping the external contour of the separating assembly, the upper one being a drive roller, the other two creating straight line geometry of separating contact stripes, two auxiliary spring-loaded pressure rollers arranged on the sides of the separating assembly increase the contact of the lowest banknote with the belts of the feeding conveyor and stabilize the separation process.

5. Device as claimed in claim 2, wherein the feeding transportation assembly (10) (Fig. 1, 2) comprises three sections unconnected to each other - two lower transporter sections (55, 56) and one upper transporter section (57), the carriers of transporters being round endless belts made of friction material and stretched on the drive drums with grooves (58) fastened on shafts and driven drums (59) mounted on axles, the feeding transport assembly being driven with a two-sided timing belt (60) engaged with cog-pulleys (61) fastened on shafts of driving drums and a cog-pulley (62) fastened on the shaft of the drive electric motor (63).

6. Device as claimed in claim 2, wherein transportation system (11) for banknotes (Fig. 1, 2) comprises a number of sections of upper and lower transporters whose carriers are round endless belts made of friction material and stretched on the drive drums with grooves (64) fastened on shafts and driven drums (65) mounted on axles, and is designed for passing banknotes sequentially through scanning devices (12, 13) of the assembly for banknote authentication and the value and unfitness degree determination, ultraviolet detector (14), magnetic mark detector (15) and banknote passage control and counting detector (16); for continuity in the transport system in the gaps between the scanning devices (12, 13) and the magnetic mark detector (15) the passage from one section to another is done on a drum thanks to a symmetrical shift in position of a pair of drawing round belts of the next section to neighboring grooves, for synchronicity in operation of different transport system parts the driving is done with one double-sided timing belt (66) engaged with cog-pulleys (67) fastened to the shafts of section drive drums and with cog-pulley (68) of the drive electrical motor (69) featuring a rotation speed stabilization system, smooth pulleys (70) fastened to axles are designed to give belts a specified direction.

7. Device as claimed in claim 2, wherein the banknote transportation systems comprises a flat drive belt instead of a timing belt, and driving cog-pulleys are replaced with flat and barrel-shaped ones for noise reduction.

8. Device as claimed in claims 2, 3, which comprises two fit banknote stacking assemblies, two unfit banknote stacking assemblies and one stacking assembly for banknotes whose authenticity and value are doubtful.

9. Device as claimed in claims 2, 3, 4, 5, which additionally comprises a banknote microprint reading scanner.

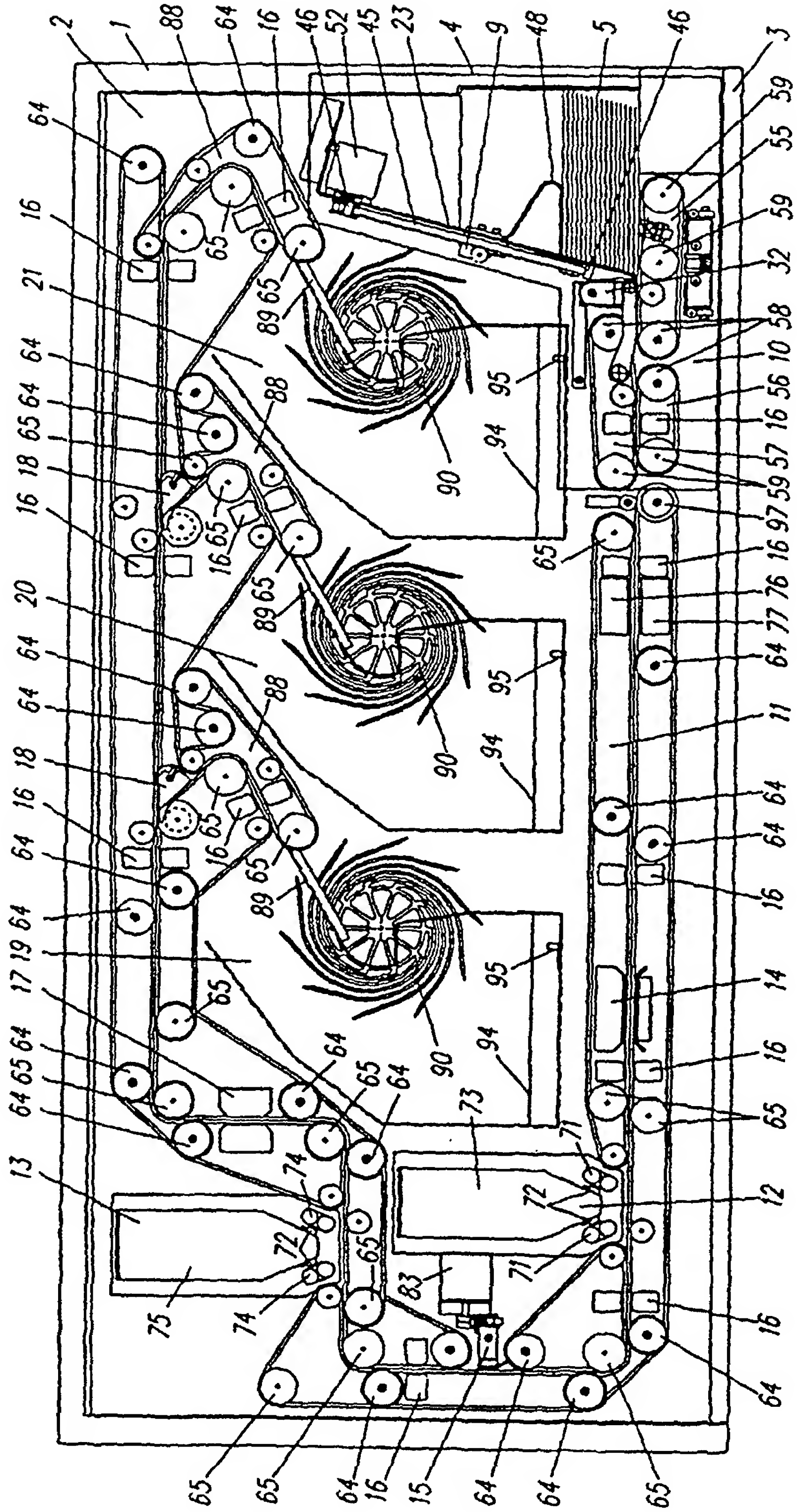

FIG.1

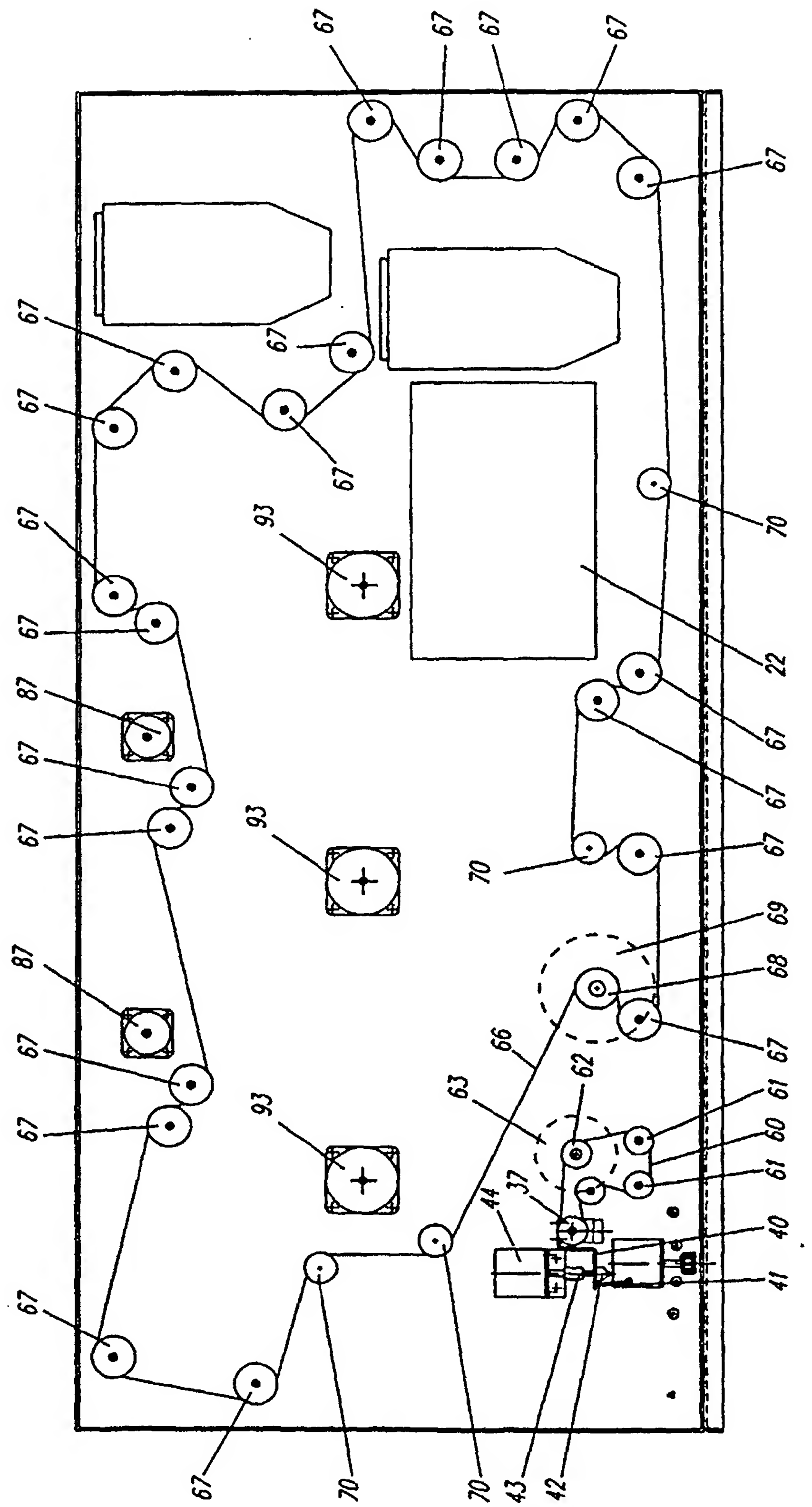

FIG.2

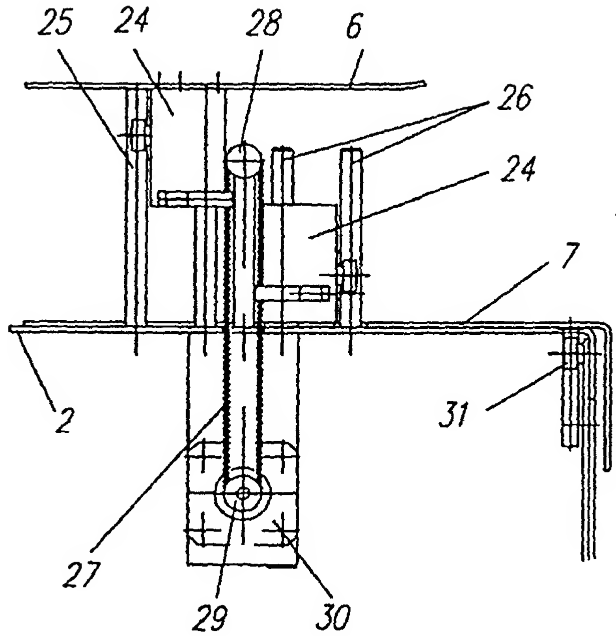

FIG.3

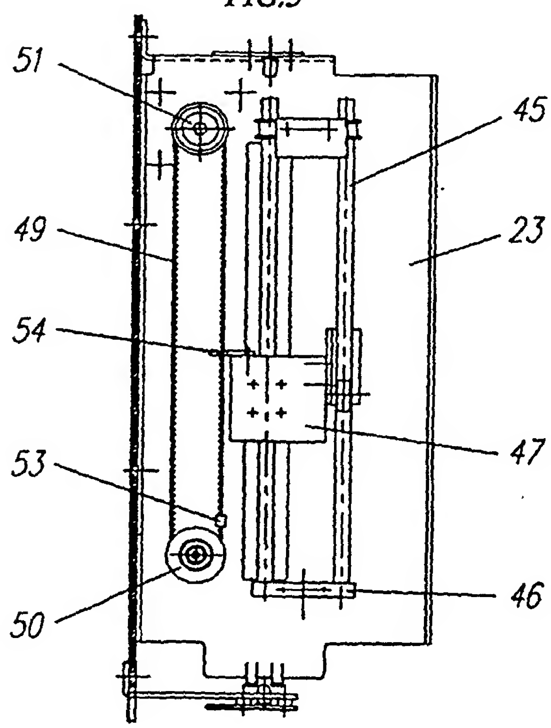

FIG.4

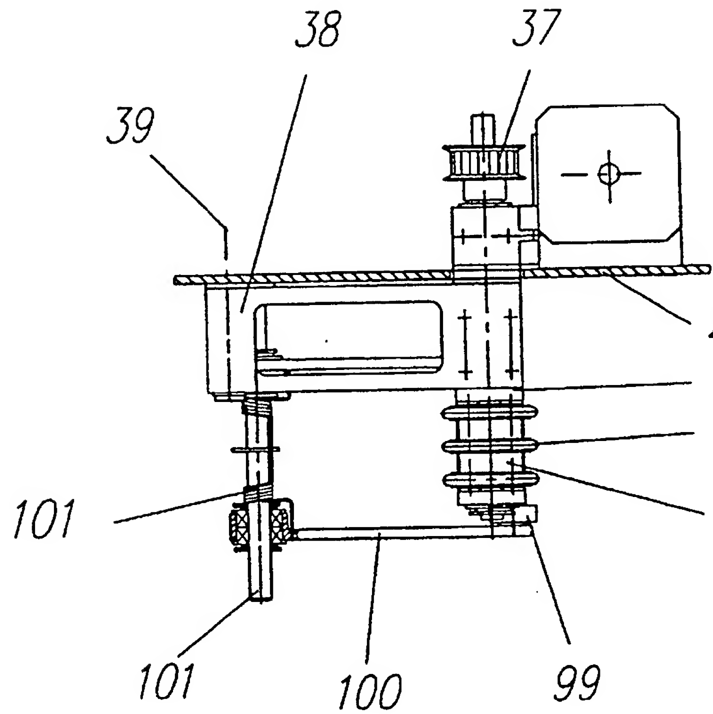

FIG.5

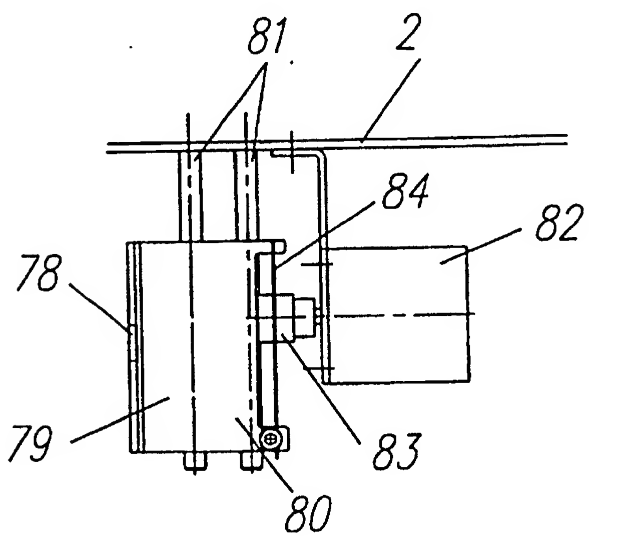

FIG.6

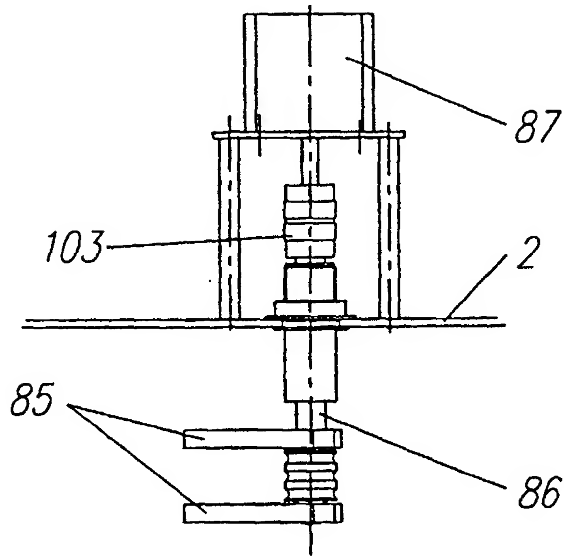

FIG.7

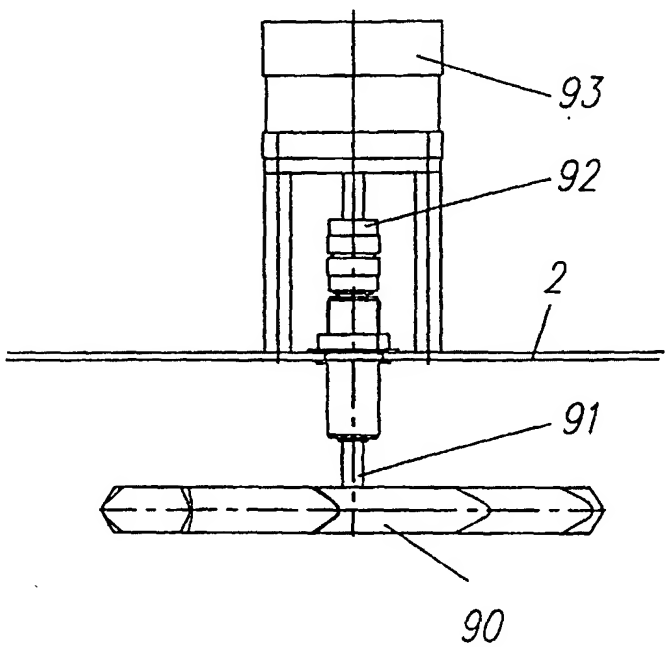

FIG.8

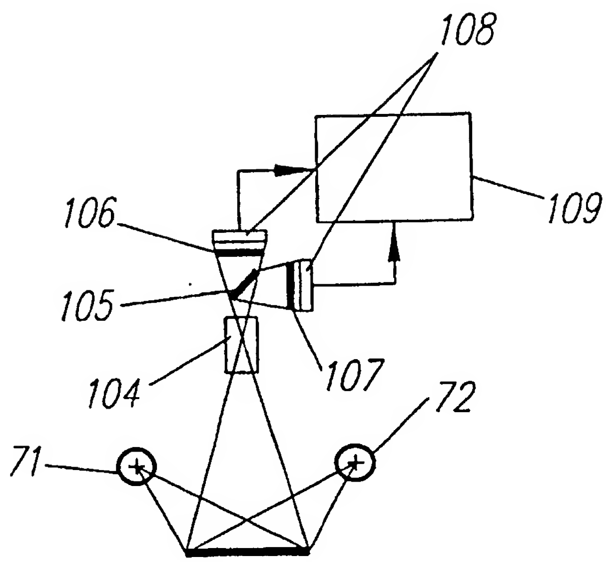

FIG.9

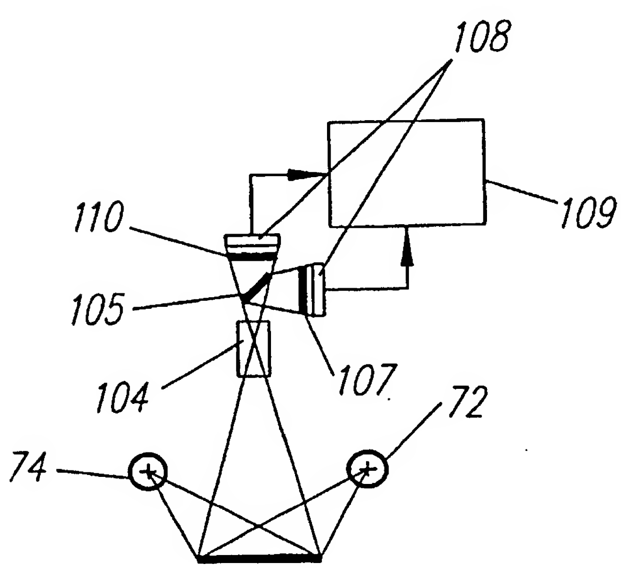

FIG.10

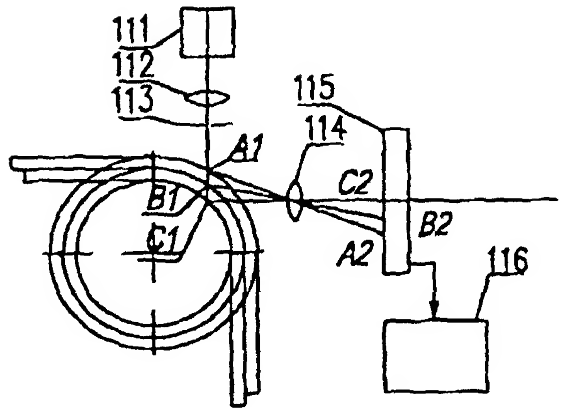
111
112
113
115
114
A1
B1
C1
C2
B2
A2
116

FIG.11

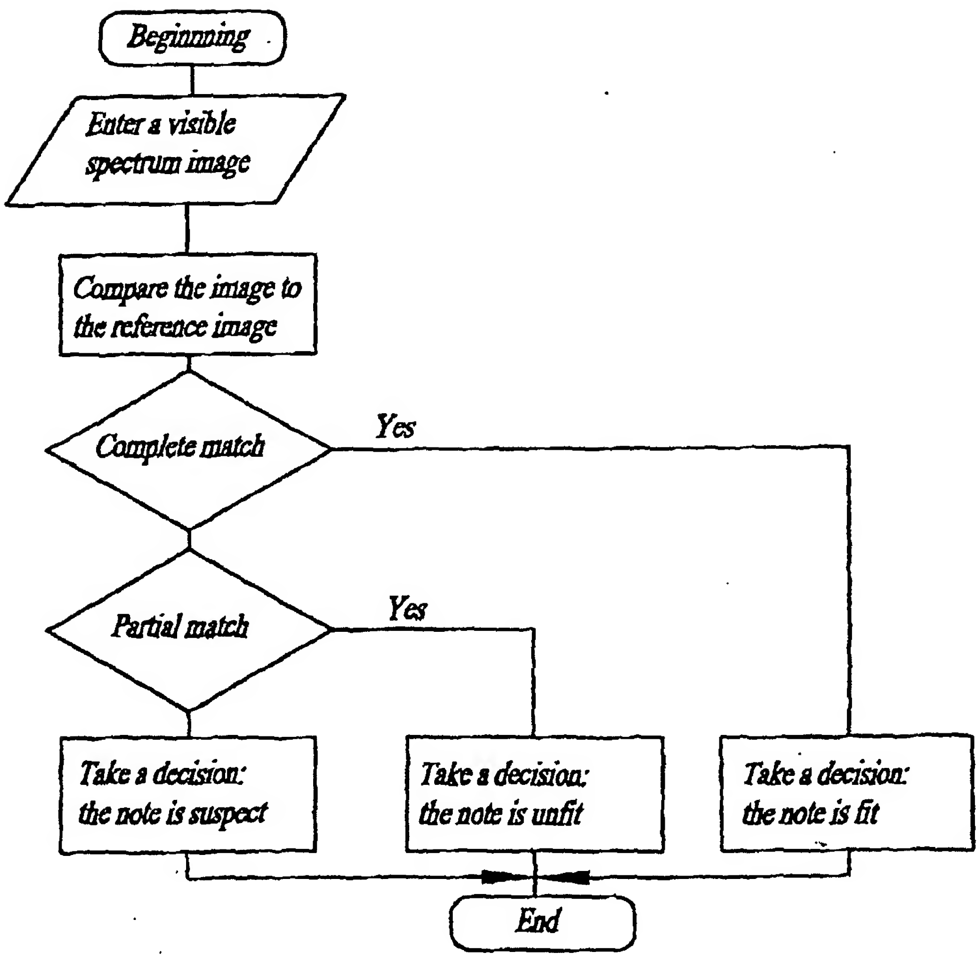
Beginning
Enter a visible spectrum image
Compare the image to the reference image
Complete match
Yes
Partial match
Yes
Take a decision: the note is suspect
Take a decision: the note is unfit
Take a decision: the note is fit
End

FIG.12

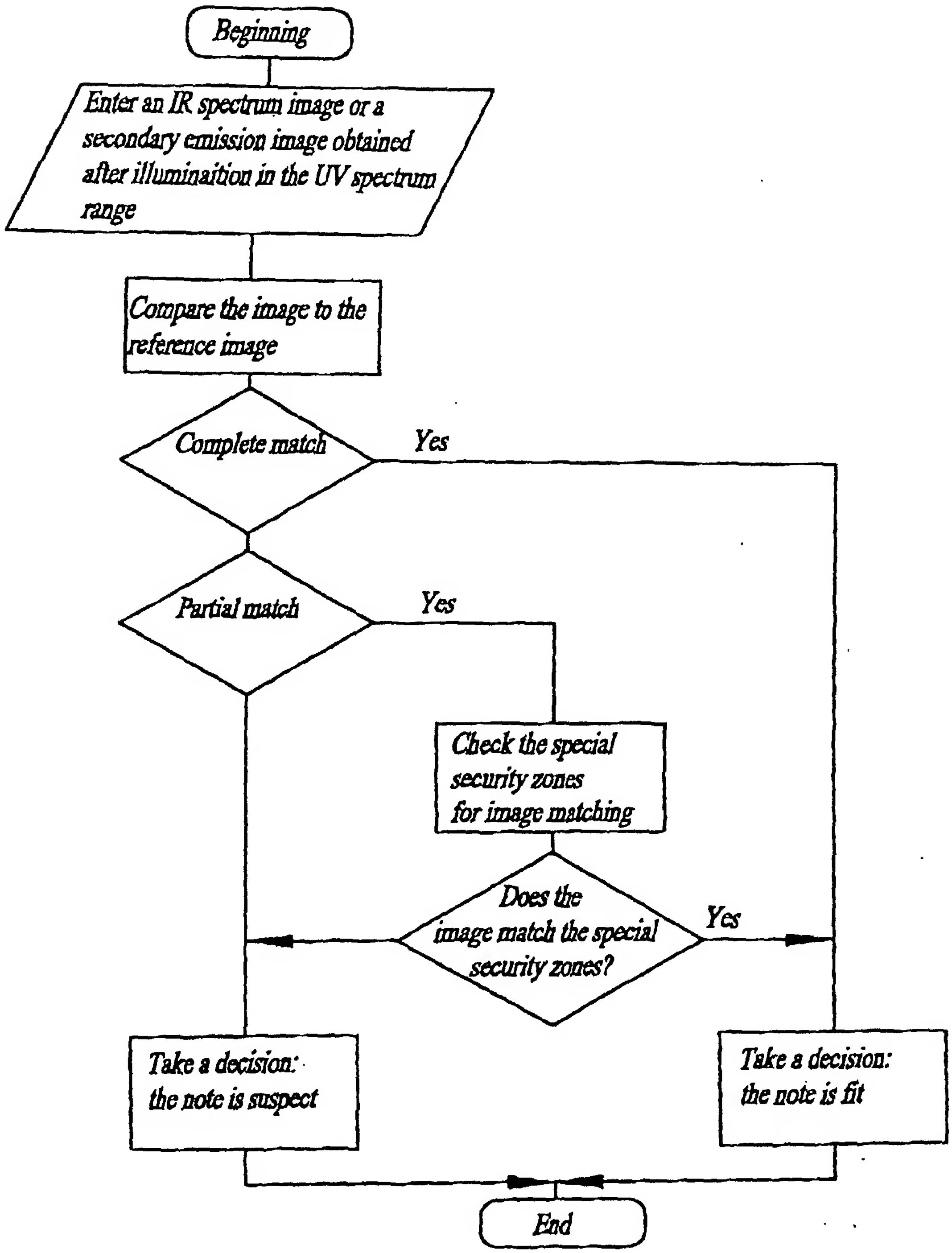
Beginning
Enter an IR spectrum image or a secondary emission image obtained after illuminaition in the UV spectrum range
Compare the image to the reference image
Complete match
Yes
Partial match
Yes
Check the special security zones for image matching
Does the image match the special security zones?
Yes
Take a decision: the note is suspect
Take a decision: the note is fit
End

FIG.13

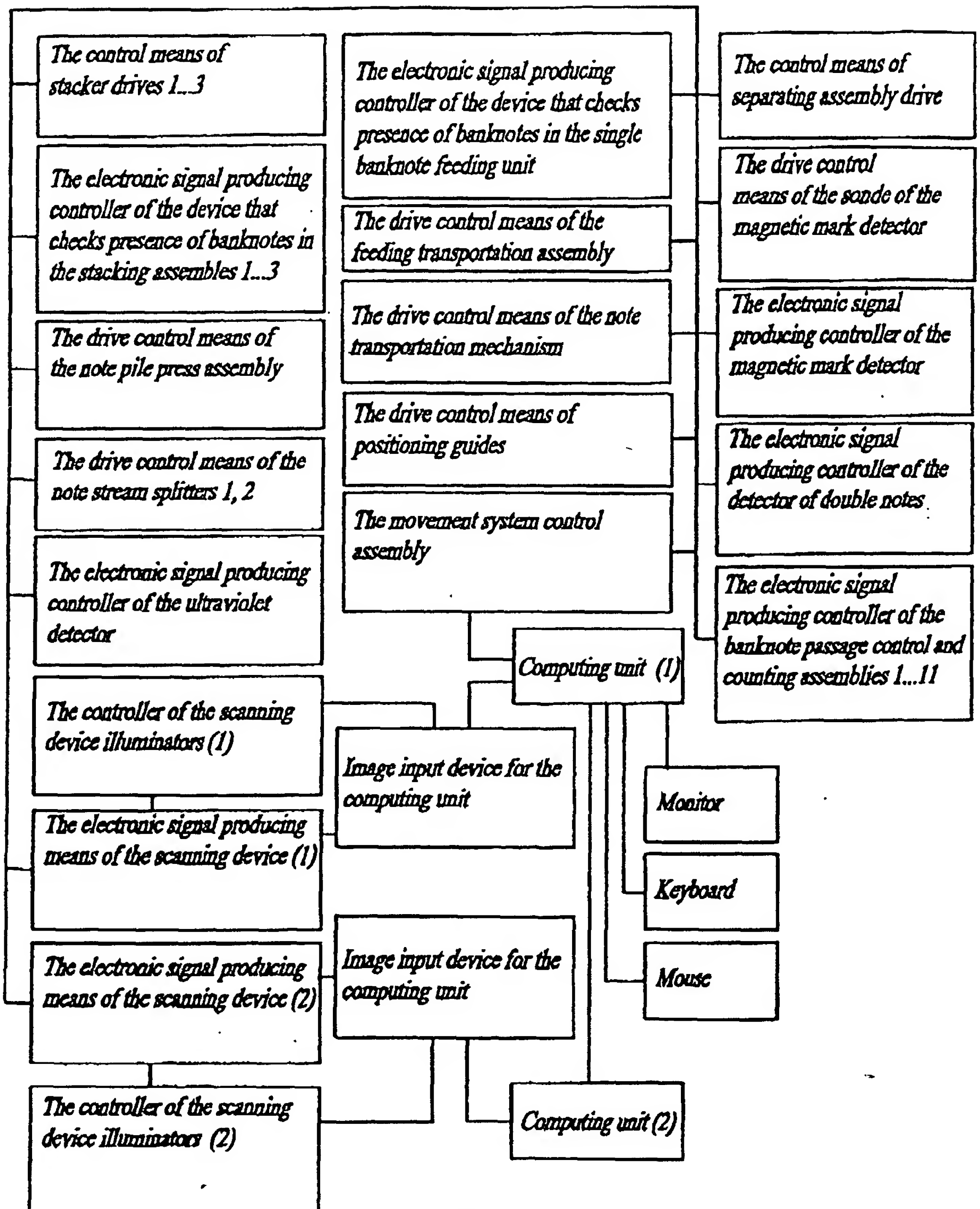
The control means of stacker drives 1...3
The electronic signal producing controller of the device that checks presence of banknotes in the stacking assembles 1...3
The drive control means of the note pile press assembly
The drive control means of the note stream splitters 1, 2
The electronic signal producing controller of the ultraviolet detector
The controller of the scanning device illuminators (1)
The electronic signal producing means of the scanning device (1)
The electronic signal producing means of the scanning device (2)
The controller of the scanning device illuminators (2)
The electronic signal producing controller of the device that checks presence of banknotes in the single banknote feeding unit
The drive control means of the feeding transportation assembly
The drive control means of the note transportation mechanism
The drive control means of positioning guides
The movement system control assembly
Computing unit (1)
Image input device for the computing unit
Image input device for the computing unit
Computing unit (2)
Monitor
Keyboard
Mouse
The control means of separating assembly drive
The drive control means of the sonde of the magnetic mark detector
The electronic signal producing controller of the magnetic mark detector
The electronic signal producing controller of the detector of double notes
The electronic signal producing controller of the banknote passage control and counting assemblies 1...11

FIG.14

INTERNATIONAL SEARCH REPORT

International application No.
PCT/RU 00/00014

A. CLASSIFICATION OF SUBJECT MATTER

IPC7 G07D 3/00, 7/00, 7/12; B65H 29/60, 29/62

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G07D 3/00, 7/00, 7/06, 7/12; Go6K 9/36, 9/46; B65H 29/60, 29/62

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP0101115 A1 (NEDERLANDSE CENTRLAE ORGANIZATIE VOOR TOEGEPAST- NATUURWETENSCHAPPELIJK ONDERZOEK) 22 February 1984 (22.02.84)	1-8
A	SU 720442 A (LENINGRADSKOE OPYTNO-KONSTRUKTORSKOE BJURO TORGOVOGO MASHINOSTROENYA) 08 March 1980 (08.03.80) column 3,4, figures 1-9	1-8
A	GB 2000487 A (G.A.O. GESELLSHAFT FUR AUTOMATION UND ORGANISATION M.B.H.) 10 January 1979 (10.01.79), abstract	2-7
A	GB 2094531 A (TOKYO SHIBAURA DENKI KABUSHIKI KAISHA) 15 September 1982 (15.09.82), abstract	2-7

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
03 April 2000 (03.04.00)	20 April 2000 (20.04.00)
Name and mailing address of the ISA/ R.U. Facsimile No.	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (July 1992)